Self declaration

The topic of this research has been prepared after through literature review of many research articles. All the references for this synopsis are mentioned in the reference section of this proposal. It is sole responsibility of the research scholar for the representation & interpretation of the contents in the research articles, papers and books compiled in this research proposal. If there is any mistake in the compilation of this research proposal then it is purely unintentional, which may be corrected if it is pointed out. Decided topic of this research proposal is researcher own idea. This has been identified after study of various yarn spinning system and by finding out gap in existing researchers research for technology of present yarn spinning setup.

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Contents

		Page No.
	Self declaration	I
	Plagiarism report	II
	Table of content	IV
Chapter 1	Introduction	1
Chapter 2	Literature Review	9
Chapter 3	Rationale of Research	31
Chapter 4	Objectives of the Study	33
Chapter 5	Proposed Plan of work	34
Chapter 6	Proposed time line for work	35
	References	36

Chapter 1

Introduction

The word Textile is a noun. It comes from the Latin word textilisa. It denotes any goods mostly clothes which are produced by weaving, knitting or felting. Materials that can be converted in to yarns and fabrics are called textile materials. Technically if those materials have spinnable length, then only they can be made into spun yarns. [1]

The history of textile is almost as old as that of human civilization. As time moves on the history of textile has further enriched itself. The oldest recorded indication of fiber usage came into the knowledge with the discovery of flax and wool fabric at 6 - 7 century BC old excavation site. In India, the culture of silk was introduced in 4000AD, while spinning of cotton traces back to 3000BC. [2]

Fibre is the basic unit of any textile material. High length to diameter ratio along with better resilience helped fibres to be converted in to desired textile products easily. The major portion of total fibre production is converted in to yarn. Till now the oldest excavated fibre samples were of flax and wool from Swiss lake (Switzerland) belongs to 6 and 7 century.

1. Fibre

The basic component of textiles is fibre from which yarns and fabrics are produced. A fibre is defined as one of the delicate, hair-like portion of the tissues of a plant or animal, or structure made out synthetically, with a minimum l/d of 100:1.

Fabric Link Textile Dictionary defines fibre as “The basic entity, either natural or manufactured, which is twisted into yarns, and then used in the production of a fabric”. [1]

There are number of fibres available in the nature, but out of which only few fibres were used in textile as raw materials. The fibres which are used as textile raw material, are grouped as textile fibre and classified on the basis of their source of availability which is explained in **Figure 1**. Further fibres can be classified as per their chemical composition and synthesis process which are out of the scope of this discussion. However brief history of introduction about different fibres as textile materials narrated in **Table 1 & 2.** Those fibres must possess certain essential (length, strength, uniformity, elongation and fineness) and desirable (lustre, porosity, cohesiveness etc.) properties.

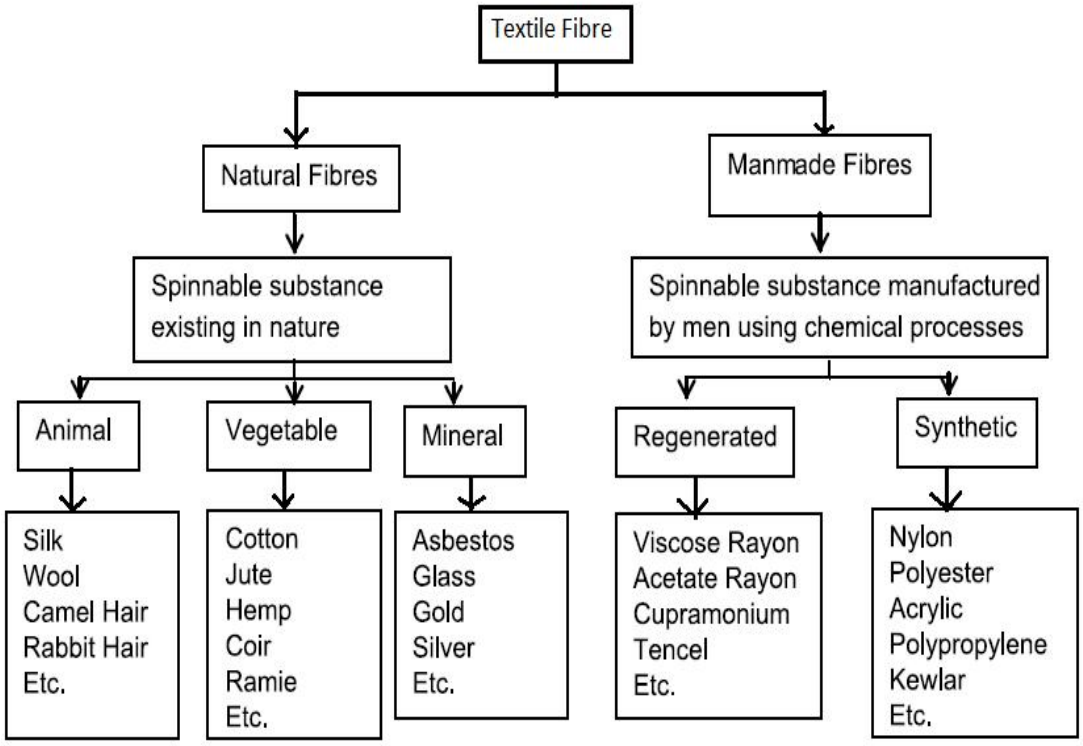


Figure 1: Classification of textile fibres. [1]

1.1. Natural Fibers. [3]

Natural fibers have been used for apparel and home fashion for thousands of years. Introduction of these material fibres can be reviewed in the **Table 1.**

Fibre	Estimated Year	Background and Production
Flax	5,000+ BC	Generally considered being the oldest natural textile fiber. Fine linen was used as burial shrouds for the Egyptian pharaohs. Largest producer Soviet States, Poland, Germany, Belgium, and France and largest exporters are Northern Ireland and Belgium.
Cotton	3,000+ BC	Its earliest use estimated between, 3000 BC to 5000 BC. Worn by Egyptians earlier than 2,500 BC. Eli Whitney's invention of the cotton gin in 1793 revolutionized the processing of cotton. The development of the power loom in 1884 brought significant improvements and variations to cotton fabric manufacturing process. Major producers United States, Soviet States, China, and India. Lesser producer includes Pakistan, Brazil, Turkey, Egypt, Mexico Iran, and Sudan.
Wool	3,000 +BC	It was used by people of the Late Stone Age. There are 40 different breeds of sheep, which produce approximately 200 types of wool with varying grades. Major producers include Australia, New Zealand, Soviet States, China, South Africa, and Argentina.
Silk	2,600 +BC	It is believed that silk was discovered by a Chinese princess. Silk is made from two continuous filaments cemented together and used to form the cocoon of the silkworm. Sericulture began about 1725 BC, sponsored by the wife of China's emperor. The secrets of cultivation and fabric manufacturing were closely guarded by the Chinese for about 3,000 years. There is a story that two monks smuggled seeds of the mulberry tree and silkworm eggs out of China by hiding them in their walking sticks. India learned of sericulture when a Chinese princess married with Indian prince. The major producer and exporter of silk is Japan.

Table 1: Brief History of Natural Fibre.

The idea about utilization of fine seed-hairs as textile fibres came at the early stage of textile evolution. Cotton fabrics were made by the Ancient Egyptian and Chinese civilizations. There are samples of cotton materials as old as 3000 BC have been found in India. There is some evidence that cotton may have been in use in Egypt in 12,000 B.C., even before the use of flax was known. Specimens of woven cotton fabric have been found in the desert tombs discovered in Peru. These pre-Inca textiles were designed and woven with immense skill. They include brocades, tapestries, crocheting and lace.

No matter where the spinning and weaving of cotton may have been developed first, there is no doubt that India was the true cradle of the cotton industry. Cotton fabrics of remarkable quality were produced as early as 1500 B.C., using only the most primitive of spinning and weaving techniques. [4]

Cotton is the backbone of the world's textile trade. Cotton provides about 50% of the world's textile fibre.[1] Many of our everyday textile fabrics are made from cotton. Cotton fabrics are capable to withstand and retain infinite variety of weave and colouring.

1.2. Man-made Fibers. [3]

Man-made fibres has been introduced very recently i.e. in 1910. A little comprehensive account of different man-made fibres can be found in **Table 2.**

Fibre	Year	First Commercial Production
Rayon	1910	It is a first man-made fiber and commercially produced first time in the United States 1910 by the American Viscose Company. Production is carried out by using two different chemicals and manufacturing techniques, two basic types of rayon were developed as a viscose rayon and cuprammonium rayon. Today, there are number of rayon producers present in the U.S. Today Aditya Birla is India's largest multinational conglomerate (with US$40B in revenue) and the world's largest producer of Viscose, manufacturing 20 percent of the world's supply of the material, which is made from wood pulp. The commitment applies to wood and pulp sourcing for all its mills, including those in Canada, Indonesia and China.
Acetate	1924	Acetate fiber was produced commercially in 1924 by the Celanese Corporation in United States.
Nylon	1939	Nylon was produced first time commercially in 1939 by the E. I. du Pont de Nemours & Company, Inc. United States. Nylon is second most used man-made fiber after polyester.
Acrylic	1950	Acrylic was produced first time in 1950 by E. I. du Pont de Nemours & Company, Inc. in United States.
Polyester	1953	Polyester was produced in 1953 by E. I. du Pont de Nemours & Company, Inc. in United States and commercialised. Polyester is the most used man-made fiber in the United States.
Triacetate	1954	In 1954 triacetate was produced commercially by the Celanese Corporation in United States first time.
Spandex	1959	Spandex was produced in 1959 as spandex fiber by E. I. du Pont de Nemours & Company, Inc. United States. It is an elastomeric man-made fiber (able to stretch at least 100% and snap back like natural rubber) used in filament form.
Polyolefin/ Polypropylene	1961	Polyolefin/polypropylene were produced commercially as an olefin fiber manufactured by Hercules Inc. in U.S. in 1961 first time. In 1966, polyolefin was the world's first Nobel-Prize winning fiber.
Microfiber	1989	First time Microfibre produced commercially by E. I. du Pont de Nemours & Company, Inc. United States in 1989. Today microfibers are produced in a variety of synthetic fibers (i.e. polyester, nylon, and acrylic). Microfiber is synthetic fiber finer than one denier or decitex/thread, having a diameter of less than ten micrometres. Micro Fiber is the thinnest, finest of all man-made fibers which is also finer than the most delicate silk. Size of human hair is more than 100 times the size of some microfibers.
Lyocell	1993	Lyocell was produced commercially in 1993 by Courtaulds Fibers Inc. U.S. under the trade name of Tencel-A. Environmental friendly, lyocell is produced from the wood pulp of trees grown specifically for this purpose. It is specially processed, using a solvent spinning technique in which the dissolving agent is recycled, reducing environmental effluents.

Table 2: Brief History of Manmade Fibre.

The basic unit of textile material as per length can be classified as staple fibre and filament fibre. The rod like structure made out of polymers with high l/d (length: diameter) ratio and minimum length of 12.5 mm can be referred as a staple fibre. This category indicates natural and manmade both. The length of filament fibre can from few meters to thousands of kilometres. Filament fibres are further converted into small length to mimic natural staple fibre induced feel in the corresponding fabric.

1.3. Staple fibres [1]

Staple itself indicates limited lengt.h. Generally all natural fibres are staple fibres except silk. Silk is only naturally occurring fibre which is present in filament form. All manmade fibres are first spun in filament form and latter converted into short staple length by cutting it into appropriate length. Manmade fibres are prepared by various spinning methods. Such as dry spinning, wet spinning and melt spinning from their polymeric chip/powder along with auxilary chemicals. A Manmade fibre doesn't contain any bio-based contamination such as trash and other impurities as they are produced in industry. In case of natural fibre, there is various types of impurities. Such as trash, dust, dirt, dry leaves in case of cotton and grease, burrs in case of wool etc. All these impurities must be separated before they get converted in yarn. [5]

1.4. Filament [1]

It is the name given to a fibre of continuous length more than 100:1 l/d. It is long enough to be used directly in a fabric without increasing its length. An example of natural filament fibre is silk. The cocoon of a silkworm contains about 360–1200 m (depending on the quality and type of cocoon) continuous twin filaments.[4] All Manmade fibres which are spun from continuous filaments are also called as filaments. The length of this continuous form of manmade fibre varies from some meters to thousands of kilometres.

1.5. Yarn [1]

Yarn is a consolidated assembly of fibres twisted together to form a continuous strand, which is suitable for weaving, knitting etc. Yarn consist of staple fibres, filaments or combination of these two **(Figure 2).** Staple fibres are converted in to long continuous strand i.e. yarn by twisting or wrapping in general. Filaments merely need grouping in order to produce the required thickness and strength. The groupings of filaments are achieved by various means such as twisting or binding with adhesive. Twist provides traverse compressive force which arrest the fibre slippage under the influence of tensile load. Twist also imparts transverse force to enhance fibre to fibre frication. It helps to

adhare these fibres in to a continuous length to form yarn. In this way a continuous length of yarn can be made even from very short fibres.

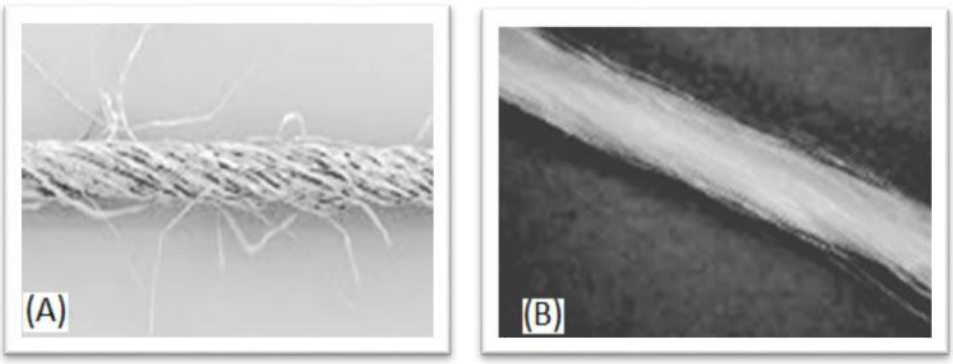


Figure 2: (A) Staple spun yarn and (B) Filament spun yarn.

1.6. Thread [1]

Thread is a combination of two or more yarn strand twisted together. Threads are singed, dyed and finished to fit into the eye of the sewing needle, or to be hand-knotted. Very extreme type of thread reaches into the area of cords and eventually ropes of all types.

1.7. Fabric [6]

The final stage of fibre is fabric. Fabric can be classified on the basis of their structure such as Woven, Non woven, Knitted and Braded fabric. Fabric is the locked (i.e. woven assembly) yarn or thread. The structure has evolved from micro structure of staple fibres to 3D macro structure of the fabric.

The uniqueness of this structure lies in the structural stability along with three dimension resistance against bending, twisting and compression & shearing force. The principle utilization of fabric is in garment sector. Domestic house hold applications includes decorative textiles, kitchen textile materials etc. Fabrics are also utilized in various technical fields (i.e. technical textiles) in various industries as well as field applications.

Other than woven fabrics, 3D macro structures such as knitted structure, braided structures also incorporate with thread or yarns in different ways. In case of nonwoven structure, staple fibres or filaments are incorporated to form non woven fabric structure with the help of physical entanglement. From the above discussion, it is clear that after fibres, the most important structure is yarn.

Linear assembly of number of staple fibre twisted together to form continuous length is called staple-spun yarn. Twist which pays major role to form continuous strand of specified length with small diameter. [2]

Hence, twisting is an important process for formation of yarn. In this process parallel fibres consolidated and holds to produce continuous structure. The conversion of fibre to yarn is miraculous step for human history. The twist enables humans to get independent and be civilized. It also withstands the evolution in the technological field. Then the basic aim of the subsequent segment i.e. literature review is to explore each and every pros & cons of existing knowledge about twisting techniques, to understand technical processes and technological gaps and to provide new dimensions to the existing yarn spinning setup.

Chapter 2

Literature review

Twist is nothing but the torsional force applied to fibre strand which bends the fibres in inclined fashion with respect to the yarn axis and helps them to consolidate with each other. The yarn strength and elongation is determined by this twisting force. Twist multiplyer (T. M.)can be used as a parameter to define twist per unit length. The direction of the twist described as per twisting i.e. counter clockwise or clockwise (S or Z). Presently there are various methods and techniques to form yarn. On the basis of twisting system yarn formation systems can be classified as shown in **Table 3.**

Sr. No.	Yarn forming method/ System	Feature	Process	Twist type	Yarn structure formed	Trade names
1.	Ring spinning	Ring and traveller	Single strand twisting	Real	S / Z Twisted	Various
			Double strand ply twisting	Real	S / Z Twist	Sirospun, Duospun
2.	Self-twist spinning	Successive S and Z twist	False twist 2 Strands Self twisting	False	S and Z Twist	Repco
3.	Wrap spinning	Wrap of fibrous core by Filament yarn or Staple fibres	Alternating S and Z Twist	False	S and Z Twist with Wrap fibre	Selfil
			wrapping Hollow Spindle	False	Twistless core and Wrapped fibre	Parafil
			Fasciated wrapping	False	Twisted core & Wrap fibre	Dref-III MJS
					Twisted core , Wrapped fibre and plied	Plyfil
4.	Open end spinning	Breaking fibre mass continuity at twist zone	Rotor spinning	Real	Z twist and wrapped	Various
			Frication spinning	Real	Z Twist and wrapped	Dref-II

Table 3: Various Novel Spinning Process with yarn characteristics. [7,8]

2.1. Twist and twist direction

Irrespective to yarn spinning method, twist in the yarn can be classified in to two broad categories i.e. real twist and false twist. The brief descriptions about these are given below.

A. Real Twist

Real twist is nothing but binding fibres with its adjacent fibres by applying torsional force to parallel strand of fibres. This remains forever after removal of torsional force in strand of fibres hence the inserted twist is regarded as real twist.

Real twist is produced in the yarn with the aid of spindles, rotors, rollers, and so on. Insertion of twist in fibre or filament strand is done with the help of twisting element which rotates around the axis of strand by holing fibre with certain angular velocity. To insert twist, one end of strand is held by some grip and other end get rotated around the axis (static point) (**Figure 3**).

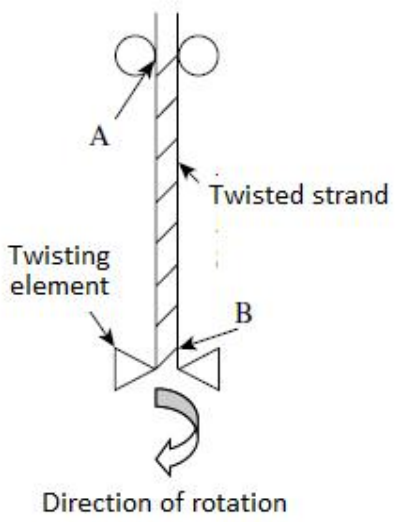


Figure 3: Real twist insertion method.

Fibre strands can be rotated in two directions i.e. clockwise and counter clockwise during twisting process. So twist can be differentiated on the basis of direction of rotation, and they are:

- S twist and [Figure 4(a)]
- Z twist [Figure 4(b)]

The direction of the twist is indicated as Z or S twist depending on the transverse orientation of the fibers, i.e. the orientation relative to the diagonals of the letters Z and S

(Figure 4). Z twist is normally used in short staple spinning, though in some cases yarns with S-twist are also produc. S-twist generally is used for plied yarns. [9]

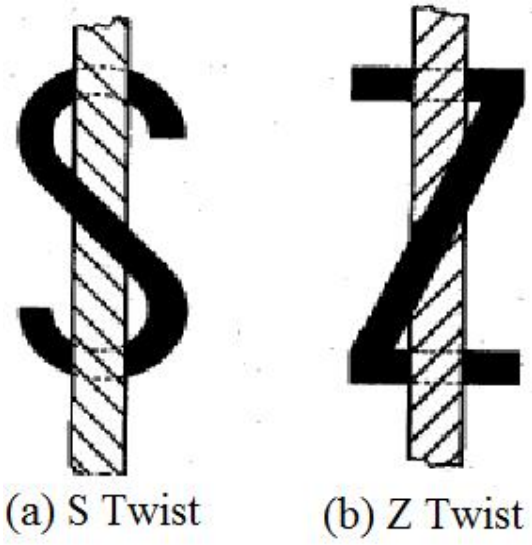


Figure 4: Twist Direction in yarn

In ring spinning real twist is imparted by spindle and traveller. TPM (Twist per Meter) can be calculated with the help of formula (i).

$$\text{Yarn Twist (TPM)} = \frac{\text{Spindle speed}}{\text{Delivery Speed}} \qquad \text{(i)}$$

Note: Spindle speed in RPM and Delivery speed is measured in m/min.

Since the spindle speed is always pushed to the maximum possible limit (and thus may be considered as constant), higher yarn twist can only be obtained through reduction in the delivery speed and hence production rate gets affected by twist insertion rate in yarn.

B. False Twist

Another type of twist is called false twist. It is called as false twist because it does not remain permanently in the structure. After the removal of torsional force fibres are rearranged to its original position. This type of twist is given to convey parallel strand of fibre over a short distance which is long relative to the fibre length. False-twist is used to provide added strength to hold the material during the transport e.g. Sliver, Roving.

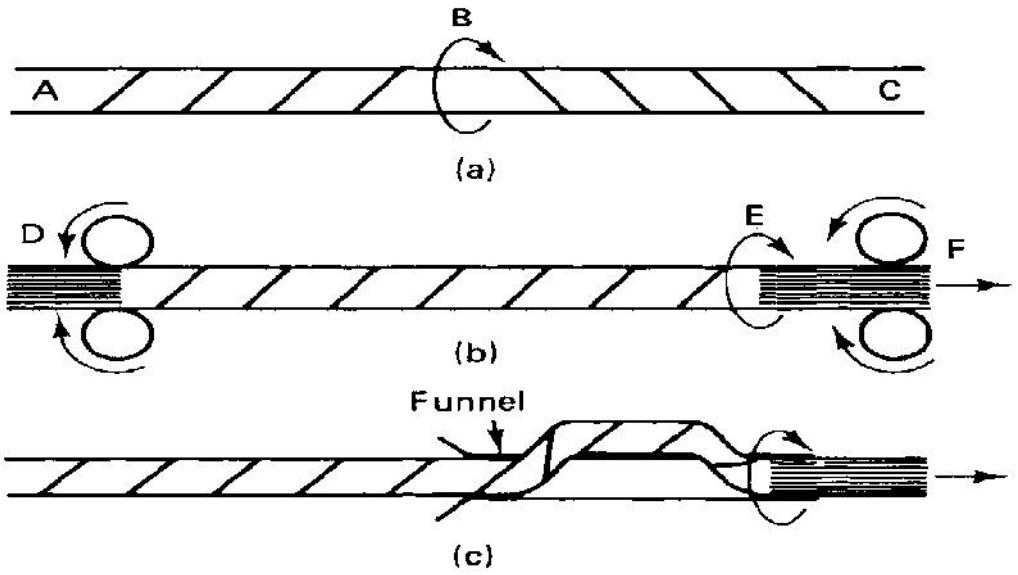


Figure 5: False twist insertion

(a) Stationary strand of fibers (b) Strand moving from left to Right

(c) Rotating funnel inserts false twist.

False twist is explained in **Figure 5**, when a stationary strand of fibres is held at AC is rotated at B **(Figure 5(a))**, then S twist is inserted between AB, and Z twist is inserted between BC. Although the algebraic sum of the twist between AC is zero, when tension is applied to such a strand. The inward radial pressure increases inter-fibre friction to such an extent that fibre slippage is avoided. Under the dynamic conditions which arise when the sliver is moving, the aforementioned situation is modified **(Figure 5(b))**. At the right-hand side of the point of rotation E, the turns of Z twist initially inserted is lost from the system because they are free to pass through the nip at F. After this initial loss of twist, the system is settle & into an equilibrium state. Assuming a linear sliver speed of 50 m/min and 1000 rev/min of the sliver at E then there will be 20 calculated turns per meter inserted into the sliver between DE (neglecting contraction due to twist insertion). As the strand moves a distance of 50 mm from left to right, the following will occur:

(1) 50 mm of twist-free sliver will enter the system at D.

(2) One turn of S twist will be inserted to the left of E, thereby maintaining the required level of S twist between DE.

(3) 50 mm of twisted material will pass point E carrying with it one turn of S twist; this will cancel out the turn of Z twist inserted between E and F, leaving the material between E and F twist-free.

In order to provide the necessary fibre cohesion, therefore, it is necessary to place the point of rotation E as close as possible to F. To improve the efficiency of twist insertion,

the sliver is passed through two holes in a rotating funnel as shown in **Figure 5(c)**. Inevitably, because of slippage, the tube is rotated at a higher speed than that required for the sliver.

The false-twist principle has important applications in the production of textured continuous filament yarns, and in woolen ring frame fibre. To control alternating S and Z directions false-twist is used in self-twist spinning, in consolidating twist-free rovings in continual worsted processing and in woolen slubbings (the equivalent of woolen rovings).[10]

2.2.Yarn Plying

Every yarn originally spun as single yarn. In certain cases yarns may be twisted together to produce a plyed yarn. Two-ply yarns, formed by twisting two single yarns with eache other. The plying twist is opposite direction to that of parent yarn twist.

With the various types of twist insertion techniques, spinning of yarns have also evolved from its premitive hand held technique to todays open end spinning. In the following segment brief evaluation of spinning is documented.

2.3. History of Yarn Spinning [7]

Yarn spinning is the process to produce continuous twisted strands (yarn) of a desired count from fibrous materials. Spinning can be categorized based on fibre staple length i.e. short staple and long staple spinning. Long staple spinning is referred for worsted spinning and jute spinning. Short staple spinning refers the spinning of short staple fibres such as cotton, polyester, viscose, and their blends. The yarn formation is usually accomplished by any one of the spinning systems i.e. ring, rotor, self-twist, friction, air jet, twist less and wrap spinning.

The basic principle of yarn spinning involves drafting, twisting and winding operations. The main function in yarn spinning is to attenuate mass of fibre by drafting along the yarn axis. Attenuation of fibres reduces the number of fibres in yarn cross section. Attenuation of fibre is carried out by varying draft in roller drafting system as per the desired yarn count. In case of rotor spinning, attenuation of fibre is done by opening sliver to single fibre stage and then combining them by back doubling process as per desired count level.

Rotor spinning and Ring spinning systems are most important for cotton yarn spinning which together account over 90% of the cotton yarn produced globally. [11]

2.4. Early Spinning Technique [7]

Previously cotton yarn spinning was carried out without the use of any tools. They were spun by stretching a thin bunch of fibres with one hand. Process encompasses drawing the material up to required thickness along with the application of twist by holding that strand in other hand fingers. Further to gain more twist in the yarn they were fastened to a stone called a whorl and twirled by hand. It is then allowed to drop vertically, thereby generated the twisting torque. In this way yarns aligned with axis of rotation get twisted. This method of twisting is called as on axis twisting.

With the spinner's thigh and the palm of the hand attenuated material rolled and twisting achieved. The relative motion between thigh and palm inserted the twist as shown in **Figure 6.**

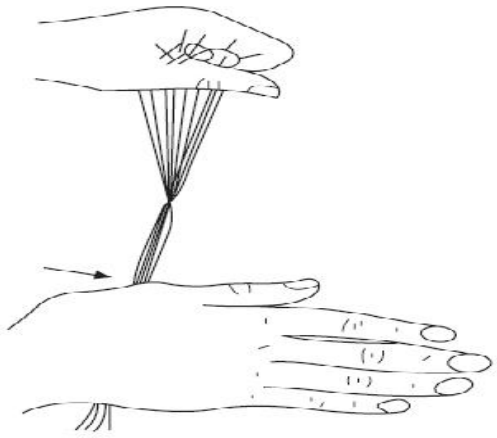


Figure 6: Early Hand Spinning Technique. [7]

In another version, a long straight stick of wood (a twig) was rolled between the thigh and palm on which the attenuated length attached to its upper end. The use of such a stick enabled the spinner to subsequently wind a spun length around the lower part of the stick. By attaching the fibre strand and twisting another length the continuity was maintained to it. Thus the concept of the spindle had therefore emerged. Also in this the twisting & winding zones where accumulated. Later the stone whorl was attached to the stick spindle. The process is known as the drop spindle spinning. However, drop spindles can have whorls made of discs of wood, stone, clay and even metal with a hole in the centre for fitting the wooden spindle.

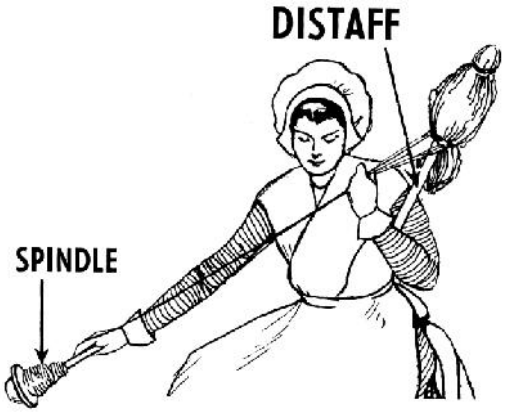


Figure 7: The Drop Spindle and Distaff System. [7]

Along with the development of the twisting device an improvement in the handling of the fibre mass during the stretching out (primitive drafting zone) for twisting was needed. It led to an accompanying hand tool for the drop spindle called the distaff. It is a short stick. Around it the prepared fibrous mass were wrapped. The fibre mass had first

to be cleaned, disentangled and loosely consolidated into a continuous rope form. The rope was loosely wound around the top end of the distaff, while the other end was held under the spinner's arm, leaving the hands free for stretching out, i.e. drawing, and twisting the fibre mass as shown **Figure 7**.

2.5. Mechanical Spinning Systems

Textile technology has evolved from manual spinning to mechanical spinning with a transition period of charkha spinning. The shift from manual to mechanical spinning had initiated industrial, economical and social revolution all over the world. In the following segment few major spinning technologies are discussed.

2.5.1. Ring Spinning [7,12]

Ring frame is still the first choice of yarn spinners because of its versatility in yarn spinning. It also produces superior yarn quality. Ring frame is capable to produce yarns with wide ranges of count and twist from a great variety of fibres

. It is also used for doubling and twisting multifold and cabled yarns. On the ring-spinning machine, the feed material is attenuated to the required linear density by a drafting system, typically a roller drafting system with three lines of rollers. The drafted fibre strand is then twisted by the ring spindle.

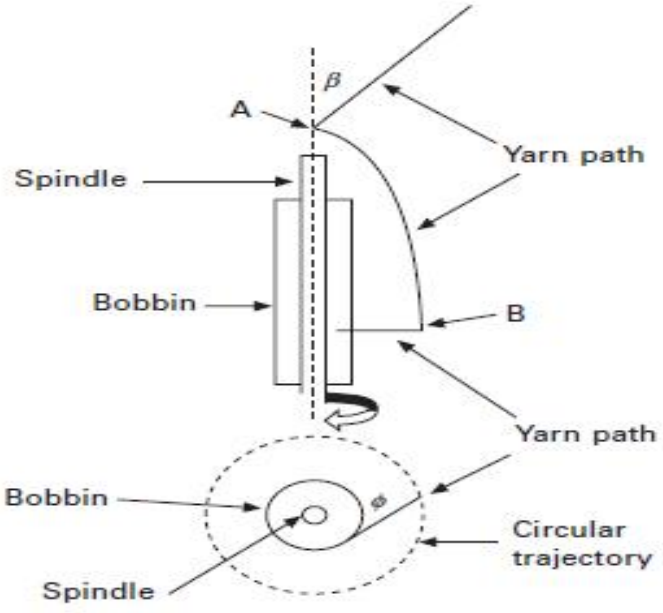


Figure 8: Yarn Path for Combined Twisting and Winding Actions. [7]

The ring spinning method utilizes roller drafting for the attenuation of a roving feed. After the years of commercial development, improvements of the roller drafting system gives more control on the fibres. Modern drafting system can produce more uniform

yarn. Apart from such engineered enhancements, this part of the ring spinning system not fundamentally different from Lewis Paul's concept. The key feature of the system is combined action of twisting and winding zone. The yarn path in the machine from flyer to bobbin is shown in **Figure 8.** It can be reasoned that in order to combine the twist and winding actions, the forming yarn must approach the spindle axis at a suitable angle, $\boldsymbol{\beta}$. The apex of this angle through which the yarn passes must be at the point, **A,** on the spindle axis. The yarn should then bend away from this point and subsequently bend a second time, at **B**, to approach tangentially, at the angle $\boldsymbol{\Phi}$ in the horizontal plane with the circumference of the bobbin mounted coaxially with the spindle. With each spindle rotation one turn of twist is inserted within the length **AB**. The right-angled bend at **B** resists twist flow more than the bend at **A**. The twist therefore propagates up to the yarn path towards the front rollers of the drafting system, instead of towards the yarn bobbin. To wind the yarn onto the bobbin during the circular trajectory, **B** rotates at a slightly slower speed than the bobbin. The difference in the speeds is effectively kept equal to the speed at which the front rollers of the drafting system issue the drafted ribbon of fibres. Hence, a length of yarn is wound onto the bobbin equal to the ribbon length issued from the front roller. The following equation (ii) expresses this balance in linear speed of the yarn

$$\boldsymbol{D}\mathrm{b}\boldsymbol{N}\mathrm{b} - \boldsymbol{D}\mathrm{C}\boldsymbol{N}\mathrm{B} = \boldsymbol{d}\mathrm{f}\boldsymbol{n}\mathrm{f} \qquad \textbf{(ii)}$$

where

Db, Nb = bobbin diameter and rotational speed

DC, NB = diameter of the circular trajectory and the rotational speed of B

df, nf = diameter and speed of the front rollers of the drafting system.

Since the ribbon of fibres leaves the front rollers at a fixed speed, it is evident from the equation that the speed of B must increase during the winding. Therefore, angle Φ must increase as the bobbin diameter increases during winding. In order to achieve the above dynamics without the use of the flyer and bobbin combination, John Thorp employed a ring, mounted on a rail coaxial with the spindle and bobbin, to define the circular trajectory and a C-shaped yarn guide called a traveller to circulate (travel) the ring. As shown in **Figure 9** the yarn passes through a lappet guide which acts as the point A, then through the traveller and then get wond on the bobbin. During the spindle rotation the frictional drag of the ring on the traveller reduces the latter's rotation sufficiently to maintain winding at a constant speed onto the bobbin.

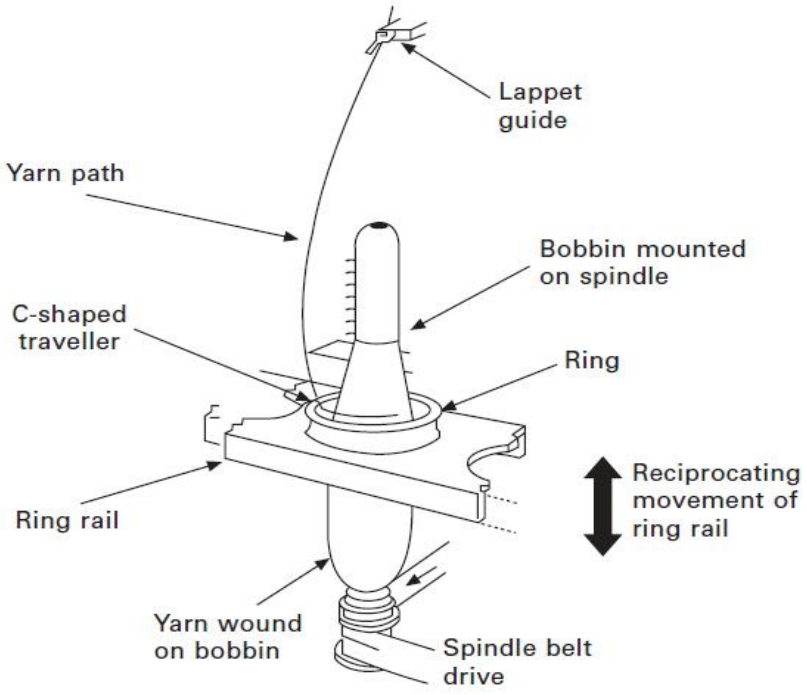


Figure 9: Key features of ring and traveller systemLoad on Ring and Traveler. [7]

By choosing correct mass of the traveller yarn tension is maintained. During the spinning process, there is always a high load on the ring running track. The traveler's centrifugal force (*F*c) depends on the travelers weight (*m*), the ring radius (*r*), and the traveler linear speed (*v*). The centrifugal force is calculated with the following formula (iii)

$$F_c = \frac{mv^2}{r_{Ring}} \qquad \text{(iii)}$$

As per the equation (iii), it is evident that this system pursues a very high value of **Fc** compared with the relatively small weight of a traveler. The centrifugal force increases in square in proportion to the traveler speed.

The centrifugal force can reach a load that is up to 8000 times the traveler weight. High loads create heat and stress to the ring surface. The traveler temperature in the contact area of traveler ring increases in cube in proportion to traveler speed **(Figure 10).**

In order to prevent premature wear on the running track when working under extremely high loads or heavy conditions, A ring treatment with very high wear resistance is preferred.

The lifetime of rings and travelers depends on two main parameters:

1. Raw material processed (lubrication potential)
2. The mechanical and thermal load on ring and traveler (speed, ring diameter, and traveler weight)

Limitation of ring & traveler system is mentioned in 2.5.1.2. segment.

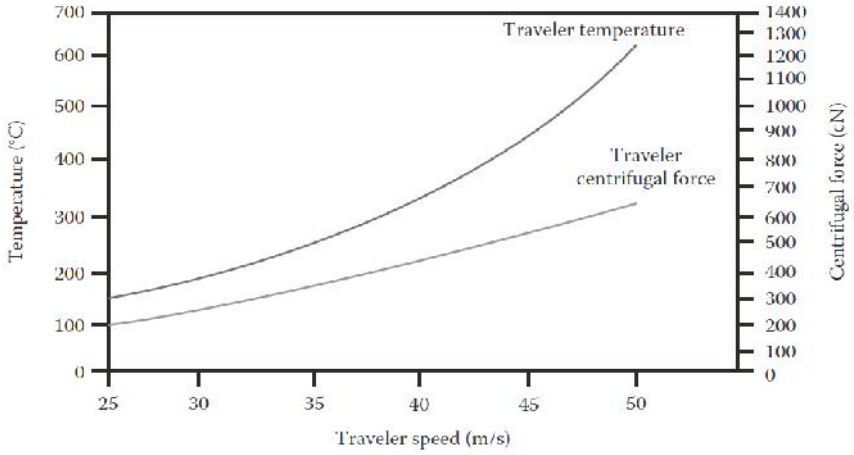


Figure 10: Influence of Traveler Speed on Its Temperature and Centrifugal Force. [11]

2.5.1.1. History of Ring frame [10]

The ring spinning frame was invented in 1832 by John Thorp. It is the most effective application of continuous drafting, twisting and winding operations at much faster production speeds than the intermittent drafting, twisting and winding of mule spinning. Afterwards, many researchers had tried to develop faster spinning system but ring spinning has remained today the most used method of yarn production, even though a number of more highly productive systems were commercially developed during the twentieth century.

The main reasons for this are as follows

1. Its flexibility in spinning of wide range of fibre types.
2. Its capability of spinning yarn at the finer end of the usable count range.
3. The better structure and properties of the ring-spun yarn than the other type of yarns.

Other than all these advantages the most prominent drawback is discussed in the next part.

2.5.1.2. Limitation of ring and traveller system [13,14]

Ring frame itself has some drawbacks related to ring and traveller system, that very same system which makes ring frame unique. To ensures the stability of the spinning balloon, the ring/traveller system must set up a certain spinning tension S, which depends primarily on the traveller speed which can be estimated by formula (iv).

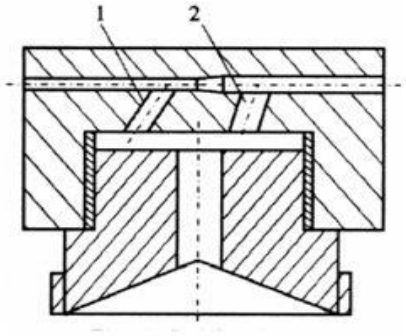
$$S \approx V_1^2 \qquad \text{(iv)}$$

With yarns of low strength (e.g. soft-twisted yarns), this yarn loading at higher speeds may lead to a steep rise in ends down. In such cases, the productivity limit of the ring-spinning machine is determined by the yarn loading. In all other cases, however, the ring/traveller system itself is the productivity limiting factor. A joint development by Bracker AG, Prosino s.r.l. and Rieter Spinning Systems has now made it possible to offer a new ring/traveller system. The new ring/traveller system (Patent pending) based on the oblique flange principle which enables the traveller speed to be raised 15% or more compared with the orthodox T flange ring system, without sacrificing the life of ring and travellers. The known disadvantages of previous oblique flange rings have been eliminated completely by the new Rieter design. Spinners now have a genuine high-performance ring/traveller system with a wide application range. Besides notably higher traveller speeds the new Rieter ring system offers further advantages for spinning of man-made fibres. In this system the danger of yarn damage is very less than with conventional T flange rings.

One another approach to overcome limits of twisting and production has been tried by one researcher by developing disc swirl spinning to produce normal yarn and core spun yarn. Scanning electron microphotographs of the disc swirl core-spun yarn have been compared with those of the air-jet spun and rotor-spun yarns. It is observed that the appearance of disc swirl core-spun yarn is similar to that of rotor-spun yarn, while the inner structure of the disc swirl core-spun yarn is found similar to that of the air-jet spun yarn. The breaking strength of disc swirl core-spun yarn is little lower than that of the ring core-spun yarn, while its breaking elongation CV% is higher. The other quality parameters of these two kinds of yarn are found to be similar. The quality of the disc swirl core-spun yarn can basically meet the need of the processes.

2.5.2. Swirl Twister [14]

A sketch of swirl twister is shown in **Figure 11**. The swirl twister is made up of two nozzles. In the first nozzle, the diameter of filament duct is 3.5 mm, and the diameter of air duct is 1.5 mm. In the second nozzle, the diameter of filament duct is 4.5 mm, and the diameter of air duct is 2.5 mm. The first nozzle gives airflow with counter-clockwise swirl at a high speed. The airflow pulls the yarn, and controls the distribution of strand in the front nip. It is beneficial to spread and separate the outer fibres. Also it causes the fibres to be freed from the nip to wind on core yarn primarily in the first nozzle. The second nozzle jets out a clockwise airflow. The speed of this airflow is higher than that in the first nozzle. Under the action of these two airflows, the core yarn is first given false twist, and then gets de-twisted with the free fibres getting wrapped on it.



1—first nozzle

2—second nozzle

Figure 11: Swirl Twister.

Quality parameter	Disc swirl core- spun yarn[a]	Ring core-spun yarn[a]
Yarn count, tex	32	32
Breaking strength, cN	244.5	285
Breaking strength CV, %	14.43	14
Breaking elongation, %	19.6	20.7
Breaking elongation CV, %	39.05	27.4
Tenacity, cN/tex	7.48	11.2
Tenacity CV, %	14.43	13
[a] Both of the yarns are 32tex T/C core-spun yarn, and wound ratio (sheath/core) is 20/80.		

Table 4: Comparison of Yarn Properties. [14]

The schematic diagram of the disc swirl spinning machine is shown in **Figure 12.** It can be utilized to produce either normal yarn or core-spun yarn. The normal yarn is produced when the core filament yarn (5) is stopped being fed. When cotton sliver comes to the

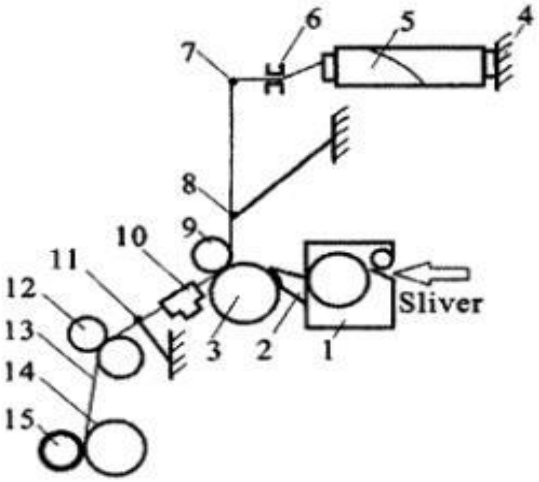
feeding device, it is held and fed successively into combing roller drafting system (1), funnel-shaped fibre conveyer (2), and disc fibre collector (3). Then the fed material is drawn and combined into a strand and reduced to much thinner size than the original sliver. The thinner sliver is then fed into front nip which is formed by disc fibre collector (3) and pressing roller (9). Fibres from front nip are fed into swirl twister (10). The same time, the filament yarn (5) is pulled from strand (4) and fed into swirl twister (10) by front nip after successively passing through tension device (6), filament yarn guide (7) and guide (8) in turn. In swirl twister (10) staple fibres are twisted around the filament yarn, and core-spun yarn (13) is formed, which is then pulled through yarn guide (11) by leading roller (12). At the end, yarn package (15) is formed with rotation of grooved drum (14). The mechanism of disc swirl spinning is shown in **Figure 13** and the spinning principle is described below.

Spinning Principle of Swril Twister

The swirl twister is made up of two nozzles, namely the first nozzle and the second nozzle which is connected with the first. The airflows in these two nozzles & rotate in opposite directions. The rotation rate in the second nozzle is higher than that in the first nozzle. The strand of fibres gets twisted under the action of the two airflows in opposite directions.

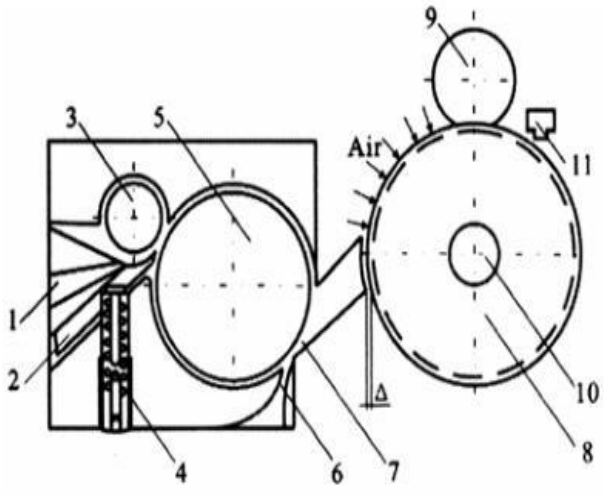
In the swirl twister the funnel (1) concentrated sliver goes into the holding area formed by feeding roller (3) and feeding board (2). Here the sliver is grasped evenly by the nip of feeding device under the pressure of spring (4) and moves forward with the rotation of feeding roller (3). Once the combing roller (5) rotates at a high speed seizes the sliver on the feeding board, the fibres in the sliver are blended, straightened out and separated gradually under the action of both saw tooth and difference of the air pressures on the surface of combining roller. Finally, fibres are peeled off and flown into funnel-shaped fibre conveyer (7) by suction. It increases gradually average speed of airflow along with the conveyer. Fibres get straightened out in airflow. The funnel-shaped fibre conveyer is connected with disc fibre collector (8). The surface of which is an eyeleted groove that can rotate. The inner part of the disc is a fixed fan-shaped air duct, which connects with a negative pressure suction system. Fibres from funnel-shaped fibre conveyer (7) are absorbed by suction in turn on the eyeleted groove, which rotates on the surface of disc fibre collector (8). Along with the rotation of the eyeleted groove, the fibres in the groove are blended and arranged in parallel order and meet nearly end to end

configuation. The suction ends when the groove rotates to the point where the groove meets with pressing roller (9). At this moment, leading ends of fibres stretch out from the point under the action of pressing roller (9), thus they become free. Under the limitation of the form of groove, the strand of fibres is drawn into swirl twister (11) by suction, and is twisted by swirling air.



1-combing roller drafting system
2-funnel-shaped fibre conveyer,
3-disc fibre collector,
4-stand
5-filaments
6-tension device
7-filaments guide
8-guide
9- pressing roller
10-swirl twister
11-yarn guide
12-leading roller
13-core-spun yarn
14-grooved drum
15-yarn package

Figure 12: Flow Diagram of Spinning Process.



1-bell,
2-feeding board,
3-feeding roller,
4-spring,
5-combing roller,
6-bypass,
7-funnel-shaped fibre conveyer
8-disc fibre collector,
9-pressing roller,
10-suction, and
11-swirl twister

Figure 13: Disc Swirl Spinning System.

2.5.3. Jet-ring spinning system [15,16]

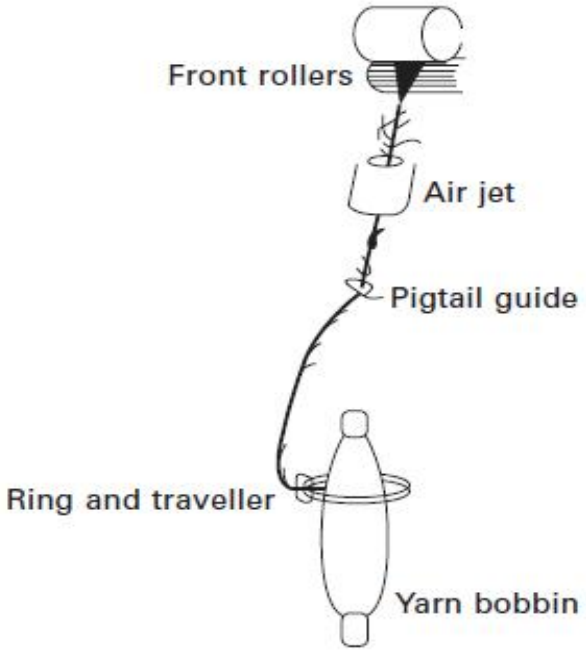


Figure 14: Jet-ring Spinning System. [15]

Jet-ring spinning technology **(Figure 14)** is amalgam of ring spinning and air-jet spinning technologies. The primary objective was to reduce yarn hairiness. In jet-ring an air-jet is positioned between the lappet (pigtail) guide and the front roller nip of the ring spinning machine. The air-jet creates upward swirling of air against the direction of movement of the yarn. Thus, it decreases the possibility of hairiness of the yarn, as in ring spinning mostly trailing hairs are generated. The swirling air current twists the yarn in the opposite direction to the main twist which is applied by the ring and traveller assembly. Therefore, over the air-jet the yarn first gets untwisted and then gets twisted again. This loosening and tightening of the structure facilitates the incorporation of some of the protruding fibres in the main yarn body. Yarn piecing is also simple in the jet-ring spinning system. However, for the best performance of the system, parameters such as air pressure and the distance between the front roller nip and the air-jet are needed to be optimized. The design parameters of the jet such as the angle of the jet orifice, the diameter of the twisting chamber and the length of the nozzle play important roles in the wrapping action of the protruding fibres.

In 2002 Cheng *et.al* [16] one researcher investigated the effect of spindle speed, air pressure, twist factor and the distance between the front roller nip and the nozzle inlet on the hairiness of cotton and polyester jet-ring spun yarns. Air pressure and yarn hairiness were negatively correlated, as expected. The hairiness reduction was more pronounced in the case of cotton yarns as compared to polyester yarns as shown in **Figure 15**. The distance between the front roller nip and the nozzle inlet has the minimum influence on yarn hairiness. However, this distance is very important for trouble-free running of the system, because any disturbance created by the air-jet can reach to the spinning triangle and cause a yarn break if the distance between the front roller nip and the nozzle inlet is very small.

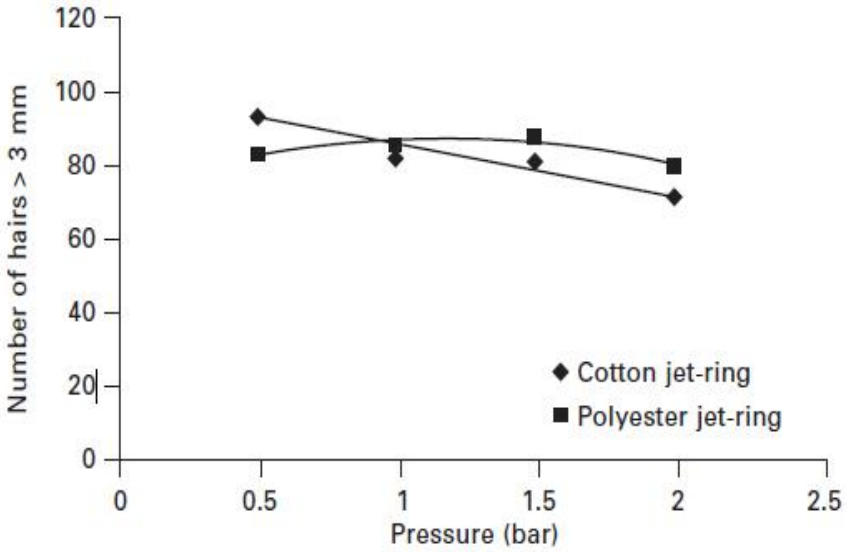


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Figure 15: Effect of Air Pressure on Yarn Hairiness in Jet-ring spinning. [16]

2.5.4. Magnetic Spinning[17]

A new addition to the spinning machine is a magnetic spinning (2006). Abdel-hady, *et.al*.[17] had tried to develop another innovative aproch towards high speed yarn spinning by using a magnetically elevated ring. In this research new concept of 'magnetic spinning' is intoduced. In their research they have designed and fabricated a lightweight rotor. The rotor was suspended magenetically inside a fixed stator. The rotor can spin freely inside this stator. A stator is equiped with four magnetic actuators which always keep the rotor in its central position. In this study rotor replaced the ring and traveler in the traditional spinning system. The concept of magnetic spinning where rotor spins freely inside stator is shown in **Figure 16**. The developed prototype is shown.

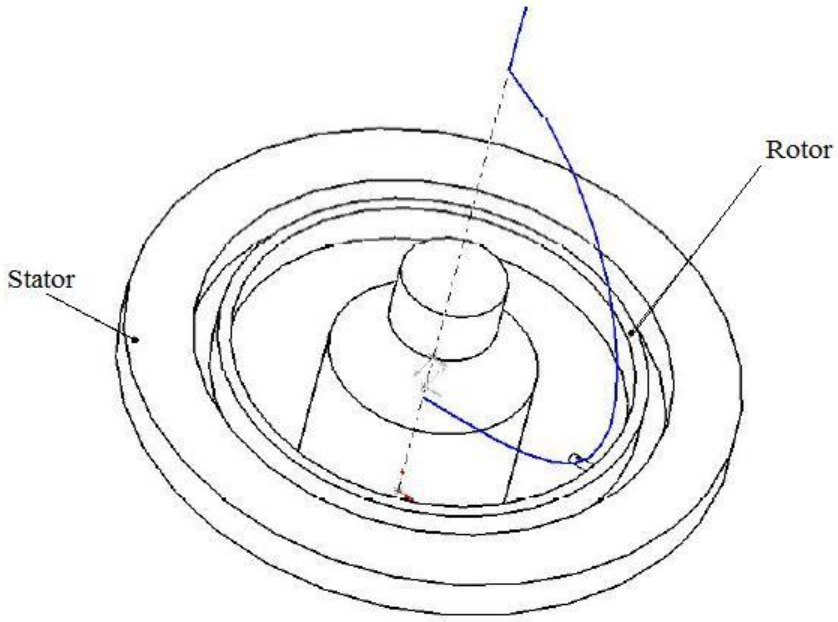


Figure 16: Magnetically suspended rotor in magnetic spinning.[17]

With the help of this magnetic spinning system directly 4 times more production rate was proposed with a rotor (ring) rpm up to 40000. The prototype is also obsolated traveller and then the problems related to that.

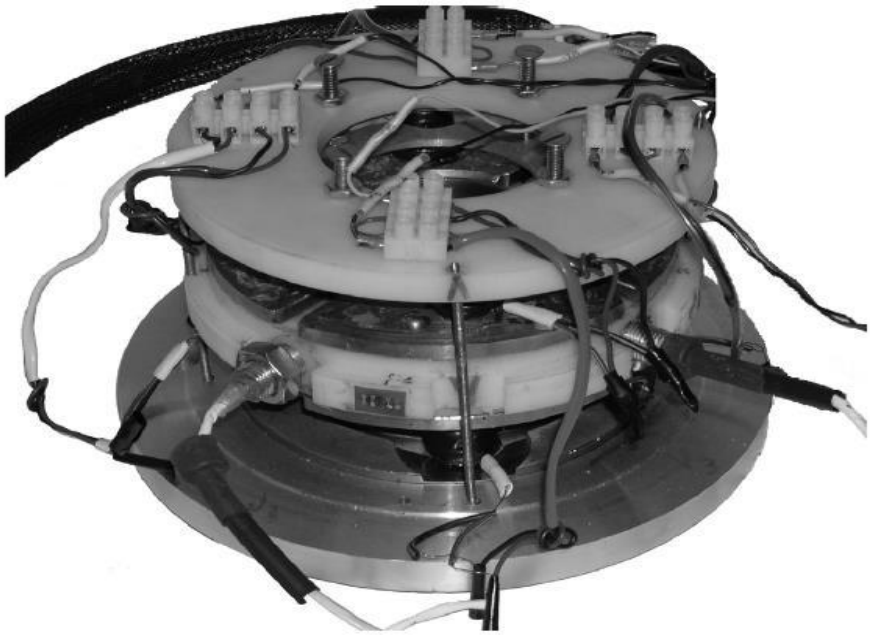


Figure17: Prototype model of magnetic spinning rotor and stator.

2.5.5. Comparison of existing spinning systems [18]

Different existing commercially viable yarn spinning systems have their own advantages and limitations. In this segment few major spinning systems are being compared with respect to their technical features (Table 6) and characteristics of the produced yarns (Figure 18- 20 and Table 7 and 8).

Twist Potential and System Limitations in Various Yarn Spinning Process

Spinning process	Twist-imparting potential/min	Imparting twist	Draft and fiber Transport
Ring	15000 – 25000	Yes	No
Rotor	80 000 - 120 000	Yes	Partly
Two nozzle Air-jet	150 000 - 250 000	No	Yes
Airjet	250 000 - 400 000	No	Yes

Table 6: Comparison of the twist potential and limitations of various yarn spinning process. [18]

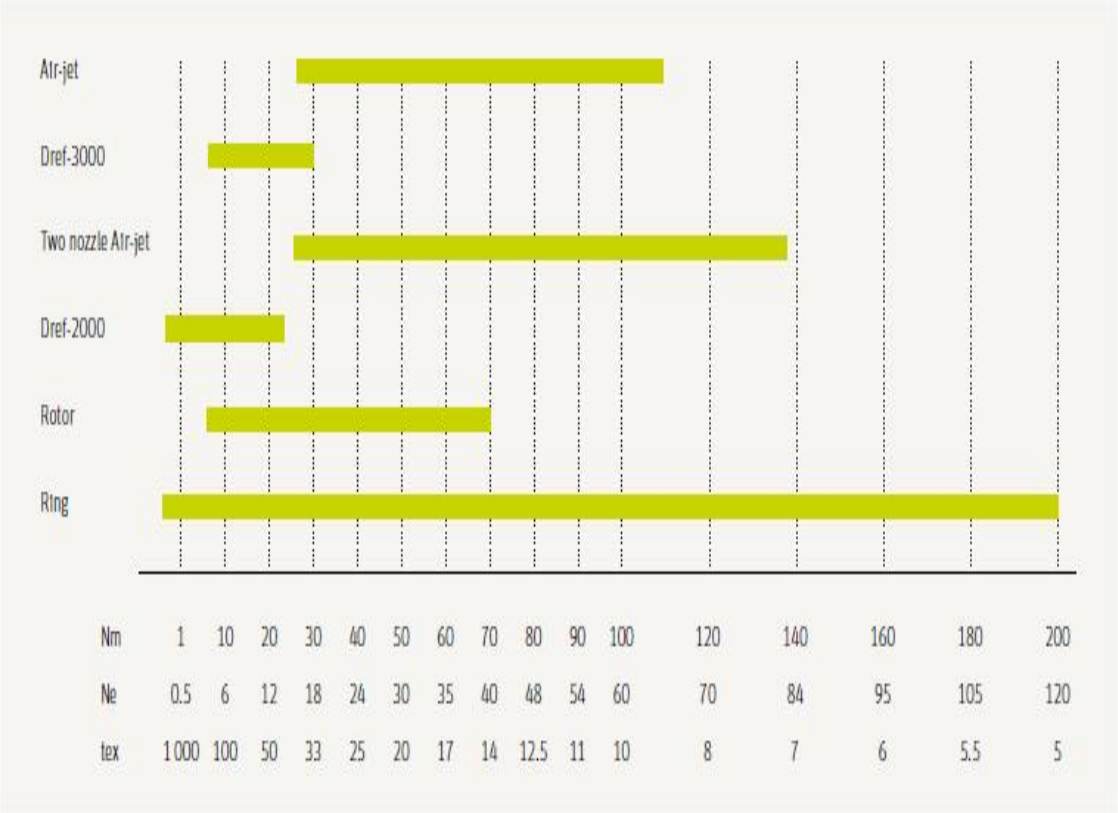


Figure 18: Yarn count range of the Industrial Yarn Spinning System. [18]

Process	Minimum	Mostly above
Ring-spun yarn (Combed)	35	60
Ring-spun yarn (Carded)	80	100
Open-end rotor	90	120
Filament-wrapped	40	50
Two nozzle Air-jet	80	100
Air-jet	80	100

Table 7: Required Number of Fibers in the Main Yarn types. [8]

Ring-spun yarn	Rotor-spun yarn	Two nozzle Air-jet yarn (false-twist)	Air-jet yarn
Tensile-Strength Values Good	Tensile-Strength Values Lower Than Ring-Spun Yarn	Good Tenacity	Good Tenacity
Good Evenness	Very Good To Good Evenness	Good Evenness	Good Evenness
High Hairiness	Higher Stiffness than Ring-Spun Yarn	Low Tendency to Snarl	Low Hairiness
Low Stiffness	Low Tendency to Snarl	High Stiffness	Stiffness Slightly Higher than Ring-Spun Yarn
High Tendency to Snarl		High Shrinkage	Good Abrasion Resistance

Table 8: Summarized characteristic properties of the main types of yarn. [18]

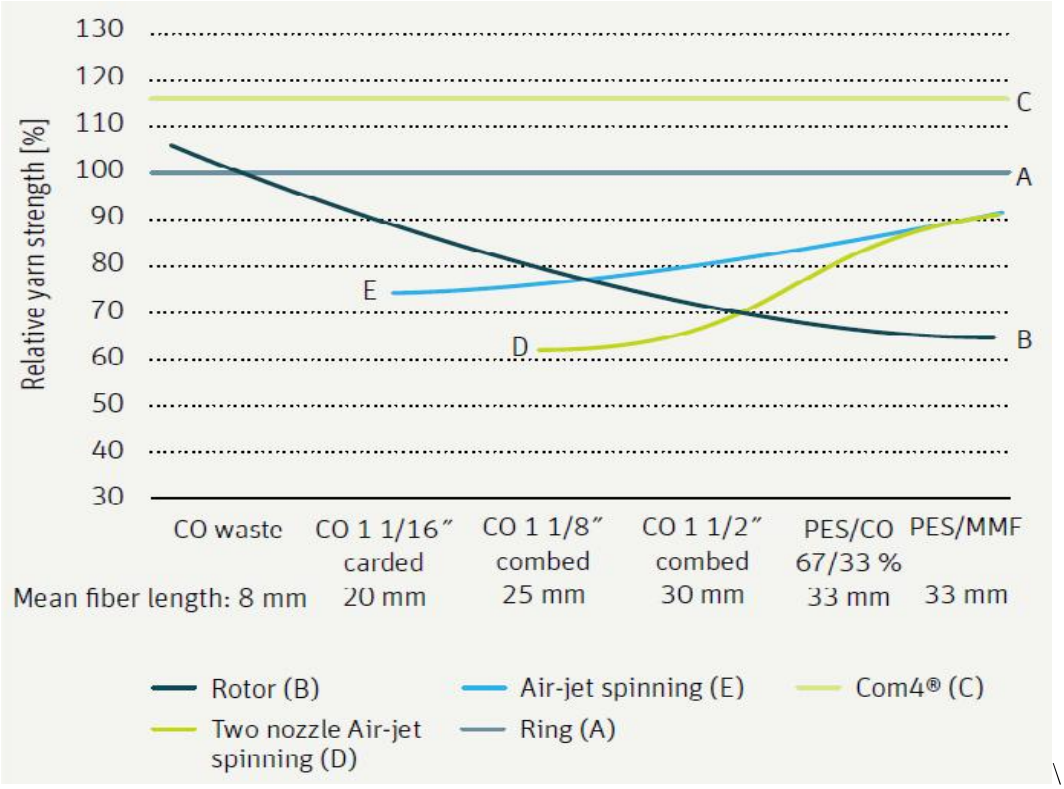
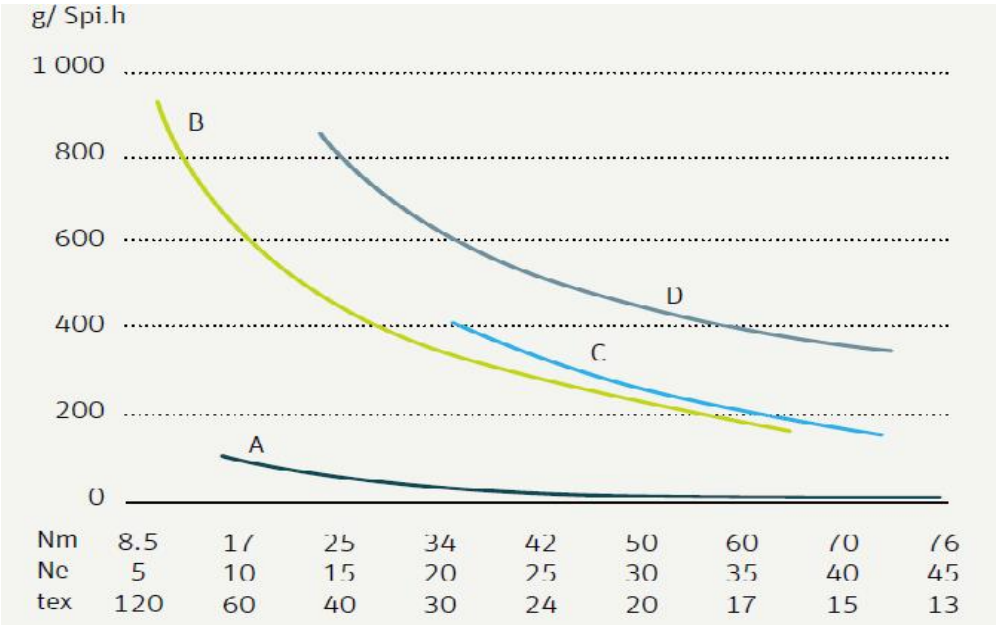


Figure 19: The relative strength values of the main yarn. [18]



A: Ring Spinning, B: Rotor spinning,

C: Two nozzles Air-jet Spinning, D: Air jet spinning

Figure 20: Production rate of different spinning methods. [18]

Chapter 3

Rationale of research

The ring spinning system had remained unchanged since its introduction in the middle of last century till the late 1960s. However, spinners knew the fact that low productivity is main constrain of ring frame for staple yarn spinning. Present ring spinning system had reached its maximum production speed with existing ring and traveller system. Among the new spinning technologies introduced in late 60s and early 70s, only rotor spinning is able to sustain as a worthy alternative to ring spinning for course and medium count ranges. The major reason to sustain this technology because of its high productivity (around 5-8 times than ring spinning production), atomization of operations with elimination of intermediate processes such as roving frame and winding machine.[19]

Spinning Methods	Actual twist-insertion rate(twist/min)	System limited by		Delivery speed (m/min)
		Twist insertion rate	Drafting and fiber-transport speed	
Ring Spinning	15,000-25,000	Yes	No	20-30
Rotor Spinning	80,000-1,15,0000	Yes	Partly	100-300
Friction Spinning	2,00,000-3,00,000	No	Yes	150-400

Table 5: Efficiency Comparison of Ring spinning with friction and OE Spinning Methods. [20]

From the literature cited in the previous segment, it is observed that there is some technical and technological limitations to increase the production of ring spun yarn. Also it is difficult to automate. Productivity of ring frame is restricted by traveller's speed. Today's modern ringframe has 45 m/s traveller speed i.e. around 25000 spindle rpm. Twisting and winding operations are combined in ringframe. It is the main restriction for further improvement in ring frame production. It limits twist insertion rate and final package size of ring frame. Numerous attempts were made till the end of the nineteenth century. To introduce a break into the fibre flow so that only the yarns end needs to be rotated to insert twist. Theoretically, with this very high twisting speed can be achieved. In addition, separation of twisting from package winding can provide much more flexibility in the form and size of the yarn package built on the spinning machine. This

increases the effiency of both, the spinning machine and the subsequent processes. Hence, less work in this area provides a huge scope to work. This identified research gap can open new doors to design ringframe to seperate twisting and winding zone and develop a new real twist insertion machine. Also ring frame is only machine which offer huge count spinning range from coarser to finer side of yarn. This type of versatility is not offered by any other machine or spinning technique.

Chapter 4

Objectives of Study

The objective of this study is to explore the existing twisting machine to find a new way / mechanism to eliminate the limitation of ring frame. In other words, the objective of this proposed research is to develop a new real twist insertion mechanism to produce final yarn without any restriction in the production, quality and count range. To achieve the same few sets of goals have been identified.

They are

1) Identification of limitations of existing yarn twisting setups from literature survey.
2) Comparison of positive real twist in yarn by existing and new modified twisting setups with respect to insertion techniques and production such as:
   - Airjet
   - Beltex
   - Friction
   - Eccentric disk

3) Design prototype for best positive twist insertion setup independent of package size.

4) To study and compare yarn properties of yarn produced with this prototype setup with conventional yarn setup. Such as uniformity, strength, twist uniformity, etc.

Chapter 5

Praposed plan of work

The proposed research idea is evolved from the review of literature. The review of literature has pointed out major gap i.e. very limited or no work in the field of separation of twisting and winding zone of the ring frame. In this path preliminary plan of work has been developed as shown in the following flow diagram (Figure 21). Detailed work plan can only be done after checking the feasibility of the prototypes.

Figure 21: Proposed Prototype for yarn twisting in present yarn spinning setup.

Chapter 6

Proposed time line for work

Year Wise	Firs Year			Second Year				Third year			
No of Weeks	6	3	3	3	3	3	3	3	3	3	3
Coursework											
Synopsis											
Literature review											
Proposal ,planning & feasibility check of prototype											
Design and implementation											
Review, Analysis and Optimisation											
Review analysis and submission of work											

Table 9: Time Line Plan of Proposed work

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